ACUTE TOXICITY SUMMARY

SULFATES

Molecular Formula	Molecular Weight	Synonyms	CAS Registry Number
$(NH_4)HSO_4$	115.12	ammonium bisulfate; ammonium hydrogen sulfate	7803-63-6
$(NH_4)_2SO_4$	132.14	ammonium sulfate	7783-20-2
$Fe_2(SO_4)_3$	399.88	ferric sulfate	10028-22-5
Na_2SO_4	142.06	sodium sulfate	7757-82-6

I. Acute Toxicity Summary (for a 1-hour exposure)

Inhalation reference exposure level	**120 μg/m³**
Critical effect(s)	small changes in airway function tests, especially in asthmatics.
Hazard Index target(s)	Respiratory System

II. Physical and Chemical Properties (HSDB, 1994)

Description	white and grayish-white crystals as solids
Density	$(NH_4)_2SO_4$: 1.769 g/cm^3 @ 20°C $(NH_4)HSO_4$: 1.78 g/cm^3 @ 25°C Na_2SO_4: 2.671 g/cm^3 $Fe_2(SO_4)_3$: 3.097 g/cm^3@ 18°C
Boiling point	H_2SO_4: 315-388°C
Melting point	$(NH_4)_2SO_4$: 235°C $(NH_4)HSO_4$: 147°C Na_2SO_4: 888°C $Fe_2(SO_4)_3$: 480°C
Flashpoint	not applicable
Explosive limits	not applicable
Solubility	soluble in water, insoluble in acetone, ethanol, and ether
Odor threshold	sulfate particles are odorless
Odor Description	not applicable
Metabolites	SO_4^{2-} conjugates

III. Major Uses or Sources

Sulfates, including sulfuric acid, are produced in ambient air through oxidation of the SO_2 and SO_3 formed from fuel combustion (CARB, 1976). Atmospheric ammonia reacts with sulfuric acid to form the ammonium salts $(NH_4)_2SO_4$ and $(NH_4)HSO_4$. Sodium sulfate occurs near marine sources. Sulfuric acid is a strong acid used as an intermediate for linear alkylbenzene sulfonation surfactants used in dyes. It is used in petroleum refining; for the nitration of explosives; in the manufacture of nitrocellulose; in caprolactam manufacturing; and as a drying agent for chlorine and nitric acid.

IV. Acute Toxicity to Humans

The hydrogen ion content of the acid sulfate exposure provides a stimulus for bronchoconstriction, especially in asthmatics (Balmes *et al*., 1989). Consequently, sulfuric acid is the most potent of the sulfates in producing airway responses, followed by $(NH_4)HSO_4$ and $(NH_4)_2SO_4$ (Schlesinger and Graham, 1992; Schlesinger *et al*., 1992; Schlesinger and Chen, 1994). A comparison of sulfate aerosols on carbachol-induced bronchoconstriction in healthy humans confirmed the above relative potencies (Utell *et al*., 1982). This Appendix also contains an acute toxicity summary for sulfuric acid.

Utell *et al*. (1983) found that exposure of asthmatics to 450 μg/m³ sulfates as H_2SO_4, but not $(NH_4)HSO_4$, for 16 minutes resulted in decreased airway conductance (SGaw). In this study, exposure to 1,000 μg/m³ of either type of sulfate resulted in decreased SGaw and decreased forced expiratory volume in one second. Utell *et al*. (1982) reported that in normal volunteers a single exposure of 0.45 mg/m³ for 4 hours resulted in increased bronchoconstriction 24 hours later.

Concomitant exposures to other pollutants in industrial areas, including SO_2, ozone, and metallic aerosols can add to or potentiate the irritancy of H_2SO_4 (Amdur, 1989). This is of particular concern for asthmatic individuals, who may be more sensitive than non-asthmatics to the irritant effects of H_2SO_4.

Amdur *et al*. (1952) demonstrated that the lowest exposure detected by odor, taste, or irritation was 1 mg/m³ H_2SO_4. The same experiment showed that a 30% increase in airway resistance in healthy individuals occurred following a 15-minute exposure to 0.35 mg/m³ H_2SO_4. Avol and associates (1979) found no significant effects on pulmonary function in groups of 6 normal or asthmatic volunteers exposed for 2 hours to 0.1 mg/m³ $(NH_4)_2SO_4$, 85 μg/m³ $(NH_4)HSO_4$, or 75 μg/m³ H_2SO_4. In contrast, adolescent asthmatics exposed to 0.068 mg/m³ H_2SO_4 for 40 minutes exhibited pulmonary changes as measured by a 6% decrease from pre-exposure control (Koenig *et al*., 1989). Avol and associates (1990) were unable to reproduce this observation by Koenig *et al*. (1989) of statistically significant respiratory dysfunction in a group of young asthmatics exposed to H_2SO_4 aerosol at concentrations near 100 μg/m³ (30 min at rest and 10 min at moderate exercise).

Normal and asthmatic subjects exposed for 2 hours to 0.075 mg/m³ ferric sulfate (0.055 mg/m³ SO_4^{2-}) showed no significant decrements in pulmonary function tests when compared to average pre-exposure values (Kleinman *et al*., 1981).

Predisposing Conditions for Sulfate Toxicity

Medical: The young may be more sensitive than adults to lethal effects, based on guinea pig LC_{50} values (Amdur, 1952). Some asthmatics are more sensitive to pulmonary irritation produced by exposure to sulfuric acid.

Chemical: Exposure to ozone may increase the irritant effects of sulfate exposure (Amdur, 1989).

Other: Factors increasing the irritancy of sulfates include (1) adding steam to sulfuric acid mist; (2) high humidity in general; (3) large particle size (> 10 µm) (Sim and Pattle, 1957); and (4) concomitant exposure to other pollutants from automobile exhaust (SO_2, ozone, and metallic aerosols) (Amdur, 1989).

V. Acute Toxicity to Laboratory Animals

The LC_{50} value for H_2SO_4 in young guinea pigs is 18 mg/m³ and in adult guinea pigs 50 mg/m³ for an 8-hour exposure (Amdur, 1952). The LC_{50} for H_2SO_4 in rats is 1,402 mg/m³ for a one-hour exposure (RTECS, 1993).

Sulfuric acid was more potent than either ammonium bisulfate or ferric sulfate in slowing particle clearance from the lungs of rats following a single 4-hour exposure to 3.5 mg/m³ (Phalen *et al.*, 1980).

Schlesinger *et al*. (1990) showed that daily one hour exposures for five days to 250 µg/m³ H_2SO_4 caused a decrease in prostaglandins E_2, $F_{2\alpha}$, and thromboxane B_2 in lavage fluid from rabbit lungs. Similarly, a single 3-hour exposure to 75 µg/m³ H_2SO_4 resulted in decreased superoxide production and tumor necrosis factor in stimulated alveolar macrophages in rabbits (Schlesinger *et al*., 1992). A single 3-hr exposure (300 µg/m³) to guinea pigs to fine (0.3 µm) diameter and ultrafine (0.04 µm) diameter H_2SO_4 caused an increase in lactate dehydrogenase, β-glucuronidase, and total protein in lung lavage fluid (Chen *et al*. 1992). Together, these results indicate localized compromises in macrophage function and development of airway responsiveness in the alveolar region of the lung.

VI. Reproductive or Developmental Toxicity

There are no studies that conclusively show reproductive or developmental toxicity linked to sulfate exposure.

VII. Derivation of Acute Reference Exposure Level and Other Severity Levels (for a 1-hour exposure)

Reference Exposure Level (protective against mild adverse effects): 120 µg/m³

Study	Utell *et al*. (1983)
Study population	17 human asthmatics
Exposure method	inhalation of 100, 450 or 1000 μg/m³ H_2SO_4 aerosol
Critical effects	decrease in airway conductance
LOAEL	1,000 μg/m³ sulfate as H_2SO_4
NOAEL	450 μg/m³ sulfate
Exposure duration	16 min
Extrapolated 1 hour concentration	120 μg/m³ (C^n * T = K, where n =1)
LOAEL uncertainty factor	1
Interspecies uncertainty factor	1
Intraspecies uncertainty factor	1
Cumulative uncertainty factor	1
Reference Exposure Level	120 μg/m³

The 24-hour California ambient air standard for sulfates is 25 μg/m³. From the supporting document (CARB Staff Report, May 4, 1976), this number was derived mainly from a study by Amdur *et al*. (1952) and five CHESS (Community Health and Surveillance System) studies (dated 1972 and discussed by Shy *et al*., 1973 and USEPA, 1974). According to the document, the CAAQS for sulfate of 25 μg/m³, 24-hour average, is approximately midway between a lower bound of 10 μg/m³ for 24 hours recommended from the CHESS data and the upper bound of 33 μg/m³ for 24 hours extrapolated from industrial experience with sulfuric acid mist. In Amdur's study the human exposure was for 15 minutes and it is unclear how the number derived remained unchanged after extrapolation to the 24-hour average. Due to this uncertainty, the CAAQS for sulfate did not appear appropriate for derivation of the 1-hour REL. However, if the standard of 25 μg/m³ for 24 hours is time extrapolated to 1 hour using C^n x t = K. where n=2, a one hour value of 120 μg/m³ is also obtained. Thus the REL is 120 μg/m³.

The 24-hour California ambient standard for particulate matter with a diameter at or below 10 microns (PM_{10}) is 50 μg/m³.

Level Protective Against Severe Adverse Effects

No recommendation is made due to the limitations of the database.

Level Protective Against Life-threatening Effects

No recommendation is made due to the limitations of the database. (NIOSH (1995) lists an IDLH of 15 mg/m³ for sulfuric acid.)

VIII. References

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